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for multiple antennas systems in the publication by G.J. Foschini and M.J. Gans, "On Limits of Wireless Communications in a fading Environment when Using Multiple Antennas", *Wireless Personal Communications* 5 6:311-335, 1998. However, it has been demonstrated (in the publication by P. Loubaton, M. Debbah and M. de Courville, "Spread OFDM Performance with MMSE Equalization", in *International Conference on Acoustics, Speech, and Signal Processing*, Salt Lake City, USA, May 10 2001) that V-BLAST algorithms are not suited for conventional SOFDM systems due to the averaging of the SNRs (signal/noise ratios) at the receiver across the carriers during the despreading step. Moreover, such approaches lead to a tremendous decoding complexity due 15 to the computation of several pseudo inverse matrices.

A need therefore exists for an OFDM communication system and decoding algorithm for use therein wherein the abovementioned disadvantage(s) may be alleviated. 20

Statement of Invention

In accordance with a first aspect of the present invention there is provided a spread OFDM wireless 25 communication system as claimed in claim 1.

In accordance with a second aspect of the present invention there is provided a spread OFDM wireless 30 communication system as claimed in claim 10.

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In accordance with a third aspect of the present invention there is provided a receiver, for use in a spread OFDM wireless communication system, as claimed in claim 11.

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In accordance with a fourth aspect of the present invention there is provided a receiver, for use in a spread OFDM wireless communication system, as claimed in claim 18.

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In accordance with a fifth aspect of the present invention there is provided a method, of operating a receiver in a spread OFDM wireless communication receiver, as claimed in claim 19.

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In accordance with a sixth aspect of the present invention there is provided a method, for performing minimum mean square error equalization in a spread OFDM wireless communication system, as claimed in claim 27.

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In one aspect, the present invention provides a new, efficient yet simple, low complexity decoding algorithm for an enhanced OFDM modulator.

25 Preferably the OFDM modulator is based on a Walsh-Hadamard transform, allowing exploitation of the mathematical properties of a Walsh-Hadamard precoder.

In one form, the new decoding algorithm consists in
30 splitting a received block into two equal parts, one of the parts being decoded first and then subtracted from

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the received vector to suppress part of the interference and the other of the parts being decoded next. This iterative procedure can be further extended by successive block splitting and results in a multi-resolution decoding algorithm. An attractive property of this algorithm is that although it still relies on the computation of pseudo-inverses, the expressions of these pseudo-inverses are easy to derive and consist simply in the product of a diagonal matrix by a Walsh Hadamard transform. Thus, using Walsh Hadamard spreading sequences, the inherent complexity penalty of a V-BLAST decoding schemes is simply removed. This allows a significant gain in performance (e.g., around 3-4dB compared to MMSE SOFDM) with only a modest increase in complexity, which motivates:

- i) the use of such new modulation schemes in practice and
- ii) their proposal as a solution for future wireless LAN standards.

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The following technical merits of the new multi-resolution decoding algorithm can be highlighted:

- Low arithmetical complexity compared to existing SIC BLAST techniques with same or better performance.
- 25 • Flexibility and scalability of the method (it is possible to adjust the number of iterations to be performed based on a performance/complexity tradeoff).
- Can be combined into all OFDM standards as a
- 30 proprietary transmission mode (since it can be

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Claims

1. A spread OFDM wireless communication system (100) comprising:
- 5 at a transmitter (110-140)
means for transmitting a spread OFDM signal;
at a receiver (160-180)
means for receiving the spread OFDM signal;
means for equalizing the spread OFDM signal
10 means for splitting the equalized spread OFDM
signal into a first plurality of portions
including a first portion and a second portion;
means for making a decision on the second
portion to produce a decided second portion;
15 means for subtracting the decided second
portion from the received spread OFDM signal to
produce a first difference signal; and
means for equalising and processing the first
difference signal to recover the first portion
20 of the received signal in which interference
due to second portion interfering terms is
substantially reduced.
2. The system of claim 1 further comprising:
- 25 at the receiver (160-180)
means for making a decision on the first
portion to produce a decided first portion;
means for subtracting the first portion from
the equalised spread OFDM signal to produce a
30 second difference signal; and

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5 means for equalising and processing the second difference signal to recover the second portion of the received signal in which interference due to first portion interfering terms is substantially reduced.

3. The system of claim 2 wherein the receiver (160-180) further comprises means for repeating processing a predetermined number of further times, with the recovered
10 first and second portions in place of the decided first and second portions, to recover more reliable estimates for the first and second portions.

4. The system of claim 1, 2 or 3 further comprising:
15 at the receiver (160-180)
means for splitting the recovered received signal into a second plurality of portions greater in number than the first plurality of portions and including a first subsequent
20 portion, a second subsequent portion, a third portion and a fourth portion;
means for subtracting the second subsequent portion, the third portion and the fourth portion from the received signal to produce a
25 first subsequent difference signal; and
means for processing the first subsequent difference signal to recover the first subsequent portion of the recovered received signal in which interference due to second,
30 third and fourth portion interfering terms is substantially reduced;

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means for making a decision on the first subsequent portion to produce a decided first subsequent portion;

5 means for subtracting the first subsequent portion, the third portion and the fourth portion from the received signal to produce a second subsequent difference signal; and

means for processing the second subsequent difference signal to recover the second subsequent portion of the recovered received signal in which interference due to first, third and fourth portion interfering terms is substantially reduced;

10 means for making a decision on the second subsequent portion to produce a decided second subsequent portion;

15 means for subtracting the first subsequent portion, the second subsequent portion and the fourth portion from the received signal to produce a third difference signal;

20 means for processing the third difference signal to recover the third portion of the recovered received signal in which interference due to first, second and fourth portion interfering terms is substantially reduced;

25 means for making a decision on the third portion to produce a decided third portion;

30 means for subtracting the first subsequent portion, the second subsequent portion and the third portion from the received signal to produce a fourth difference signal;

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means for processing the fourth difference
signal to recover the fourth portion of the
recovered received signal in which interference
due to first, second and third portion
5 interfering terms is substantially reduced; and
means for making a decision on the fourth
portion to produce a decided fourth portion.

5. The system of claim 4 wherein the receiver (160-180)
10 further comprises means for repeating processing a
predetermined number of further times, with the decided
first subsequent portion, the decided second subsequent
portion, the decided third portion and the decided fourth
portion in place of the recovered first subsequent
15 portion, the recovered second subsequent portion, the
recovered third portion and the recovered fourth portion
respectively, to recover more reliable estimates for the
first subsequent portion, the second subsequent portion,
the third portion and the fourth portion.

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6. The system of claim 4 wherein the second plurality
of portions is an integer multiple of 2 that is greater
than 2.

25 7. The system of any preceding claim wherein the means
for equalising and processing comprises:
first matrix multiplication means for multiplying by
a first diagonal matrix having elements dependent on
channel coefficients; and

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second matrix multiplication means for multiplying
by a second matrix which is a subset of a Walsh
Hadamard matrix.

- 5 8. The system of any preceding claim wherein the means
for equalising and processing comprises means for
performing minimum mean square error equalization.
9. The system of any preceding claim wherein the means
10 for transmitting a spread OFDM signal comprises means for
spreading by performing a Walsh Hadamard transform.

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10. A spread OFDM wireless communication system (100)
comprising:

at a transmitter (110-140)

means for transmitting a spread OFDM signal;

5 at a receiver (160-180)

means for performing minimum mean square error
equalization having:

first matrix multiplication means for
multiplying by a first diagonal matrix
10 having elements dependent on channel
coefficients; and

second matrix multiplication means for
multiplying by a second matrix which is a
subset of a Walsh Hadamard matrix.

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11. A receiver (160-180) for use in a spread OFDM wireless communication system (100), the receiver comprising:

5 means for receiving a wireless spread OFDM signal;
means for equalizing the spread OFDM signal
means for splitting the equalized spread OFDM signal into a first plurality of portions including a first portion and a second portion;
10 means for making a decision on the second portion to produce a decided second portion;
means for subtracting the decided second portion from the received spread OFDM signal to produce a first difference signal; and
15 means for equalising and processing the first difference signal to recover the first portion of the received signal in which of interference due to second portion interfering terms is substantially reduced.

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12. The receiver of claim 11 further comprising:

means for making a decision on the first portion to produce a decided first portion;
means for subtracting the first portion from
25 the equalised spread OFDM signal to produce a second difference signal; and
means for equalising and processing the second difference signal to recover the second portion of the received signal in which interference
30 due to first portion interfering terms is substantially reduced.

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13. The receiver of claim 12 wherein the receiver further comprises means for repeating processing a predetermined number of further times, with the recovered
5 first and second portions in place of the decided first and second portions, to recover more reliable estimates for the first and second portions.

14. The receiver of claim 11, 12 or 13 further
10 comprising:

means for splitting the recovered received signal into a second plurality of portions greater in number than the first plurality of portions and including a first subsequent
15 portion and a second subsequent portion, a third portion and a fourth portion;
means for subtracting the second subsequent portion, the third portion and the fourth portion from the recovered received signal to
20 produce a first subsequent difference signal;
and
means for processing the first subsequent difference signal to recover the first
25 subsequent portion of the recovered received signal in which interference due to second, third and fourth portion interfering terms is substantially reduced;
means for making a decision on the first
30 subsequent portion to produce a decided first subsequent portion;

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means for subtracting the first subsequent portion, the third portion and the fourth portion from the received signal to produce a second subsequent difference signal;

5 means for processing the second subsequent difference signal to recover the second subsequent portion of the recovered received signal in which interference due to first, third and fourth portion interfering terms is

10 substantially reduced;

means for making a decision on the second subsequent portion to produce a decided second subsequent portion;

15 means for subtracting the first subsequent portion, the second subsequent portion and the fourth portion from the received signal to produce a third difference signal;

20 means for processing the third difference signal to recover the third portion of the recovered received signal in which interference due to first, second and fourth portion interfering terms is substantially reduced;

means for making a decision on the third portion to produce a decided third portion;

25 means for subtracting the first subsequent portion, the second subsequent portion and the third portion from the received signal to produce a fourth difference signal;

30 means for processing the fourth difference signal to recover the fourth portion of the recovered received signal in which interference

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due to first, second and third portion
interfering terms is substantially reduced; and
means for making a decision on the fourth
portion to produce a decided fourth portion.

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15. The receiver of claim 14 further comprising means
for repeating processing a predetermined number of
further times, with the decided first subsequent portion,
the decided second subsequent portion, the decided third
10 portion and the decided fourth portion in place of the
recovered first subsequent portion, the recovered second
subsequent portion, the recovered third portion and the
recovered fourth portion respectively, to recover more
reliable estimates for the first subsequent portion, the
15 second subsequent portion, the third portion and the
fourth portion.

16. The receiver of any one of claims 11-15 wherein the
means for equalising and processing comprises:
20 first matrix multiplication means for multiplying by
a first diagonal matrix having elements dependent on
channel coefficients; and
second matrix multiplication means for multiplying
by a second matrix which is a subset of a Walsh
25 Hadamard matrix.

17. The receiver of any one of claims 11-16 wherein the
means for equalising and processing comprises means for
performing minimum mean square error equalization.

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18. A receiver (160-180) for use in a spread OFDM
wireless communication system, the receiver comprising:
means for performing minimum mean square error
equalization having:

- 5 first matrix multiplication means for
 multiplying by a first diagonal matrix having
 elements dependent on channel coefficients; and
 second matrix multiplication means for
 multiplying by a second matrix which is a
10 subset of a Walsh Hadamard matrix.

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19. A method of operating a receiver (160-180) in a spread OFDM wireless communication system (100), the method comprising:

5 receiving a wireless spread OFDM signal;
equalizing the spread OFDM signal
splitting the equalized spread OFDM signal into
a first plurality of portions including a first
portion and a second portion;
making a decision on the second portion to
10 produce a decided second portion;
subtracting the decided second portion from the
received spread OFDM signal to produce a first
difference signal; and
15 equalising and processing the first difference
signal to recover the first portion of the
received signal in which of interference due to
second portion interfering terms is
substantially reduced.

20 20. The method of claim 19 further comprising:
making a decision on the first portion to
produce a decided first portion;
subtracting the first portion from the
equalised spread OFDM signal to produce a
25 second difference signal; and
equalising and processing the second difference
signal to recover the second portion of the
received signal in which interference due to
first portion interfering terms is
30 substantially reduced.

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21. The method of claim 20 further comprising repeating processing a predetermined number of further times, with the recovered first and second portions in place of the decided first and second portions, to recover more
5 reliable estimates for the first and second portions.

22. The method of claim 19, 20 or 21 further comprising:
splitting the recovered received signal into a
second plurality of portions greater in number
10 than the first plurality of portions and
including a first subsequent portion and a
second subsequent portion, a third portion and
a fourth portion;
subtracting the second subsequent portion, the
15 third portion and the fourth portion from the
recovered received signal to produce a first
subsequent difference signal; and
processing the first subsequent difference
signal to recover the first subsequent portion
20 of the recovered received signal in which
interference due to second, third and fourth
portion interfering terms is
substantially reduced;
making a decision on the first subsequent
25 portion to produce a decided first subsequent
portion;
subtracting the first subsequent portion, the
third portion and the fourth portion from the
received signal to produce a second subsequent
30 difference signal;

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5 processing the second subsequent difference
signal to recover the second subsequent portion
of the recovered received signal in which
interference due to first, third and fourth
portion interfering terms is substantially
reduced;
making a decision on the second subsequent
portion to produce a decided second subsequent
portion;
10 subtracting the first subsequent portion, the
second subsequent portion and the fourth
portion from the received signal to produce a
third difference signal;
processing the third difference signal to
15 recover the third portion of the recovered
received signal in which interference due to
first, second and fourth portion interfering
terms is substantially reduced;
means for making a decision on the third
20 portion to produce a decided third portion;
means for subtracting the first subsequent
portion, the second subsequent portion and the
third portion from the received signal to
produce a fourth difference signal;
25 processing the fourth difference signal to
recover the fourth portion of the recovered
received signal in which interference due to
first, second and third portion interfering
terms is substantially reduced; and
30 making a decision on the fourth portion to
produce a decided fourth portion.

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23. The method of claim 22 further comprising repeating processing a predetermined number of further times, with the decided first subsequent portion, the decided second
5 subsequent portion, the decided third portion and the decided fourth portion in place of the recovered first subsequent portion, the recovered second subsequent portion, the recovered third portion and the recovered fourth portion respectively, to recover more reliable
10 estimates for the first subsequent portion, the second subsequent portion, the third portion and the fourth portion.

24. The method of claim 22 wherein the second plurality
15 of portions is an integer multiple of 2 that is greater than 2.

25. The method of any one of claims 19-24 comprising:
multiplying by a first diagonal matrix having
20 elements dependent on channel coefficients; and
multiplying by a second matrix which is a subset of a Walsh Hadamard matrix.

26. The method of any one of claims 19-25 comprising
25 performing minimum mean square error equalization.

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27. A method for performing minimum mean square error equalization in a spread OFDM wireless communication system (100), the method comprising:

- 5 multiplying by a first diagonal matrix having elements dependent on channel coefficients; and
multiplying by a second matrix which is a subset of a Walsh Hadamard matrix.